December 18, 1890.

Lieut.-General STRACHEY, R.E., Vice-President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read :—

I. "On a Determination of the Boiling Point of Sulphur, and on a Method of Standardising Platinum Resistance Thermometers by reference to it." By HUGH L. CALLENDAR, M.A., Fellow of Trinity College, Cambridge, and E. H. GRIFFITHS, M.A., of Sidney Sussex College, Cambridge. Communicated by J. J. THOMSON, F.R.S., Cavendish Professor of Physics. Received November 29, 1890.

(Abstract.)

Experiments by different observers have shown that electrical resistance thermometers afford the most convenient and accurate method of measuring temperature through a very wide range. By selecting a particular thermometer as the standard, and directly comparing others with it, it has been found possible to attain a degree of accuracy of the order of 0°·001 in the relative measurements between 0° and 100° C., and of the order of 0°·01 at 450° C.

In a previous communication* it has been shown that, if t be the temperature by air thermometer, and if pt be the temperature by platinum resistance thermometer, the difference between them is very closely represented from 0° to 700° C. by the formula

$$d = t - pt = \delta \{\overline{t/100}|^2 - t/100\} \ldots\ldots\ldots (d).$$

The value of the constant δ for a particular wire was found to be 1·570.

The object of the present paper is to describe a method of finding the value of this constant for any such thermometer, by means of a single observation at some known fixed point other than 0° or 100° C.

The boiling point of sulphur happens to be the most convenient for this purpose. We have therefore made a careful determination of this point by reference to the standard air thermometer, and have given a full description of the method and apparatus which we have

* Callendar, 'Phil. Trans.,' A, 1887, p. 161.

found most suitable for standardising platinum thermometers by means of it.

The paper is divided into three parts.

Part I contains a description of the method and apparatus employed in comparing the platinum thermometers used in this investigation with the air thermometer at a temperature very near the boiling point of sulphur.

Part II contains the determination of the actual boiling point of sulphur by means of the thermometers thus standardised, and a description of the method and apparatus to be used in standardising other platinum thermometers. A table is also given reduced from a previous series of observations of other fixed points which may be used for the same purpose.

Part III contains a comparison of the platinum and air thermometers between 0° and 100°, and shows that the δ-formula holds accurately between those limits.

The determination of the boiling point of sulphur was made by means of three platinum thermometers, L, M_1, and M_2, constructed out of the wire used in the experiments of 1887, before referred to.

Full descriptions of these thermometers are given in the paper. They were furnished with double electrodes for measuring the resistance of the connecting wires at each observation, their insulation was carefully tested, and all due precautions were taken to guard against thermal effects and other sources of error.

Thermometers M_1 and M_2 were standardised by direct comparison with an air thermometer at the boiling point of sulphur. Full particulars are given of the details of the observations and calculations, showing the limits of error of the experiments.

The expansion of the glass forming the bulb of the air thermometer was determined both by the method of linear expansion, and also by using the bulb itself as a mercury weight thermometer. The values found by the two methods agreed very closely.

The small changes of the volume of the bulb were determined from time to time during the progress of the experiments. The final observations were not taken till the thermometer had reached a fairly steady state.

The limit of accuracy attainable with this air thermometer was found to depend chiefly on that of the barometric readings. The barometer used was therefore verified by a careful comparison with the standard metre scale.

The iron-tube apparatus in which the platinum and air thermometers were compared was so constructed as to be capable of being maintained at a constant temperature by a steady flow of sulphur vapour for any length of time.

Observations were taken with it on two separate days. On each

occasion the temperature was kept steady to 0°·1 for about two hours. Allowing for the difference of the atmospheric pressure, the temperature attained was the same on both days.

The results of the comparison were in perfect agreement with the experiments of 1887, and showed that the δ-coefficient of the wire had not altered appreciably in the interval.

The apparatus which we have found most convenient for standardising platinum thermometers by means of the boiling point of sulphur consists of a wide glass tube, 40 cm. long and 4 cm. in diameter, with a spherical bulb at the end. Tubes of this kind are commonly used to heat Victor Meyer's vapour-density apparatus. For brevity we have called it a "Meyer" tube.

The outside of the tube is thickly padded with asbestos wool, with the exception of the lower half of the bulb, and of a short length of 3—5 cm. at the top, which serves as a condenser. The tube is filled with sulphur to a level of 3 or 4 cm. above the bulb, and is heated by a Bunsen burner. The gas is adjusted so as to keep the level of the vapour near the top of the tube, which is covered with asbestos card to prevent the sulphur catching fire.

Our experiments have shown that a thermometer inserted in an apparatus of this kind will not attain the actual temperature of the vapour, unless it is protected from radiation to the sides of the tube, and from the condensed liquid which runs down the stem. The lowering of temperature due to radiation, &c., may readily amount to upwards of 2° at the boiling point of sulphur.

The method which we have adopted for screening the thermometer is to bind an umbrella of asbestos card on to its stem a short distance above the bulb. Two coaxial tubes are hung on to this umbrella to screen the thermometer from radiation. We have found that glass is not sufficiently opaque to heat radiation at this temperature. The inner tube at least should be of metal.

To avoid superheating of the vapour, it is necessary to make sure that the level of the liquid sulphur stands well above that part of the bulb which is exposed to the flame.

Using these precautions, we have found that the temperature by normal air thermometer at constant pressure of the saturated vapour sulphur boiling freely under a pressure, of 760 mm. of mercury at 0° C., and g = 980·61 C.G.S. (sea level in lat. 45°), is

$$t = 444^{\circ}{\cdot}53 \text{ C.}$$

The value given by Regnault* is nearly 4° higher than this; but in the account which he gives of his experiments he has pointed out several sources of error, and it is evident that he did not place much confidence in his results.

* 'Mémoires de l'Institut,' vol. 26, p. 526.

The close agreement between the air thermometer experiments of 1887 and the present series, leads us to conclude that the number above given is probably correct to a tenth of a degree, and that it may be safely used for standardising platinum thermometers.

The method which we recommend for standardising platinum thermometers is briefly as follows:—Observe the value R_s of the resistance in sulphur vapour in an apparatus such as we have described. Calculate the value of pt_s by the formula

$$pt_s = 100\ (R_s - R_0)/(R_{100} - R_0).$$

Find the temperature t of the sulphur vapour, corresponding to the corrected barometric pressure H_0, from the formula

$$t = 444{\cdot}53 + 0{\cdot}082\ (H_0 - 760).$$

The appropriate value of δ is then given by the equation

$$t - pt = \delta\ \{\overline{t/100}|^2 - t/100\}.$$

We have made use of this method to reduce the results given in a previous communication, "On the Determination of some Boiling and Freezing Points by means of the Platinum Thermometer,"* and we find that the values of t deduced from the observations with several thermometers of different patterns and with very different coefficients, are in remarkably close agreement. The results found with the three best thermometers are given in the following table:—

Table of Boiling and Freezing Points reduced by Formula (d).

Nature of experiment.	Thermometers used.			Mean.
	E.	F.	G.	
B.p. of aniline .... (760 mm.)	184·11	184·13	184·14	184·13
,, naphthalene .... ,,	217·88	217·96	217·98	217·94
,, methyl salicylate .... ,,	222·98	223·08	—	223·03
,, benzophenone...... ,,	305·82	305·87	305·78	305·82
,, triphenyl methane (770·8 mm.)	356·47	—	356·41	356·44
,, mercury .... (760 mm.)	356·74	356·82	356·71	356·76
Freezing point of tin	231·66	231·66	231·73	231·68
,, bismuth...............	269·18	—	269·25	269·22
,, cadmium..............	320·70	—	320·66	320·68
,, lead	327·66	—	327·71	327·69
,, zinc..................	417·55	—	417·59	417·57

The fixed points given in the above have not been so carefully determined as the boiling point of sulphur. They rest entirely on the

* See Griffiths, 'Phil. Trans.,' A, 1891.

assumption of the accuracy of the δ-formula, and have not been directly referred to the air thermometer. We believe, however, that they are probably correct to 0°·1 C., and that they may be safely used to standardise thermometers of limited range, in cases where it may happen to be inconvenient to make use of the sulphur point.

In comparing the platinum and air thermometers between 0° and 100° C. observations were taken at intervals of 5° all the way up. The mean deviation of the observations from the parabolic formula (d) is only 0°·006. This corresponds to the limit of accuracy of the barometric readings, and there is no reason to suppose that the δ-formula may not represent the difference even more closely than this.

The same platinum thermometer has been compared with several mercury thermometers standardised at Kew.* The result seems to show that the Kew standard reads 0°·1 C. lower than our air-thermometer at 30°.

II. "On the Generic Identity of *Sceparnodon* and *Phascolonus*." By R. LYDEKKER, B.A. Communicated by Professor W. H. FLOWER, C.B., F.R.S. Received November 19, 1890.

[PLATE 1.]

In the year 1872, Sir Richard Owen described and figured in the 'Phil. Trans.'† two imperfect lower jaws of a large extinct Wombat, from the Pleistocene of Queensland, under the name of *Phascolomys* (*Phascolonus*) *gigas*, the term *Phascolonus* being employed in a subgeneric sense. The species *Phascolomys gigas*, it should be observed, was founded by the same writer‡ at an earlier date, upon the evidence of a detached cheek-tooth. Subsequently Sir Richard Owen§ described and figured certain imperfect upper incisors, from Queensland and South Australia, characterised by their peculiarly flattened and chisel-like shape, under the new generic name *Sceparnodon*, which was suggested from their contour.

In cataloguing the fossil Mammalia in the collection of the British Museum,|| I was at once struck by the circumstance that, while the upper incisors of the so-called *Phascolomys gigas* were unknown, there were no cheek-teeth which could be referred to *Sceparnodon*, and it accordingly occurred to me that the two might prove to be identical. Support was afforded to this conjecture by the following circumstances:—1st. The incisors of *Sceparnodon* agreed fairly well in relative size

* Griffiths, 'Brit. Assoc. Report,' 1890.

† Page 257, Pl. 36—38, 40.

‡ 'Encyclopædia Britannica,' 8th ed., vol. 17, p. 175 (1859).

§ 'Phil. Trans.,' 1884, p. 245, Pl. 12.

|| 'Cat. Foss. Mamm. Brit. Mus.,' pt. 5, pp. 157—159 (1887).